A Comparative Study of Three Heat Exchangers

Edward C. Berger
Chas. T. Miller Hospital
St. Paul, Minnesota

Several factors govern the efficiency of a heat exchanger. The first is the temperature differential between the heat exchange fluid and the blood. Efficiency dcreases as the differential decreases. Secondly, as the velocity of blood increases over or through the exchanger, efficiency will usually increase (Fig. 1). Thirdly, as the velocity of the exchange fluid increases, efficiency again will usually increase. Other factors, such as surface area, etc., are inherent in the design of the unit and are beyond the control of the user.

For the past several years, the Brown-Harrison exchanger, in all its various forms, has been the yardstick used to measure other heat exchangers. A different unit is either better or worse. On the other hand, to users of the DeWallLillehei bubble oxygenator, the Zuhdi coil has become their standard. Now, a new exchanger has been designed by Dr. Alan C. Hymes and made available by Phelan Manufacturing Company. It consists of an eleven foot, Teflon-coated length of one quarter inch tubing wound into a coil to fit into the bubble column of the DeWall-Lillehei apparatus. As part of another project, it became necessary to compare these three types of heat exchangers.

Method and Results:

Each unit was studied individually as a part of the DeWall-Lillehei pump oxygenator using a Kimray Tank as a source of exchange fluid. Fluid temperatures of O degrees C. for cooling and 43 degrees C. for warming were used on each perfusion during which the full cooling and rewarming cycle was performed at several different flow rates. A Pemco-Brown-Harrison type was used without volume reducing rods. The Zuhdi was tested with a 1¼" I.D. helix and a constant level of 700 cc's was maintained during all tests.

Figures 2 and 3 depict loss or gain of heat in calories per minute. Calories per minute was calculated by multiplying the differential between the blood input and output of the exchanger (in degrees C) by the flow (in cc/min).

DISCUSSION:

The flow of the exchange fluid through the exchangers was governed by the design of the exchangers. Average flow through the Pemco was 8000 cc per minute. Through the Phelan unit only 2000 cc per minute was circulated due to its small bore. In a separate test, a high pressure circulating pump increased the flow to 2800 cc per mnute with a corresponding increase of exchanger efficiency. The Pemco reached its peak output one minute after the onset while the others did not peak until two minues after the onset. During the warming cycle, the Pemco reached an average of 17,500 calories per minute the first minute after starting and donated 4,100 calories to the blood before the others could reach maximum output. The graphs record the second minute.

This new heat exchanger seems to gain its advantage over the Zuhdi (which has actually more surface area) from the fact that the blood is in a thin, filmy state and is gently turbulent for better exposure and mixing. It can possibly be simply adapted to the Travenol disposable oxygenator and many other bubble oxygenator systems as well. A modification to increase the velocity of exchange fluid through this unit would theoretically bring it closer to the capabilities of the Pemco while preserving the advantage of requiring no priming, a necessity in hemodilution procedures.

Expressing the working value of the exchanges in calories per minute seemed to be the most concrete approach. The standard efficiency rating used by some investigators varies with the blood flow and also with the system of calculation of which there are several. Depicting exchanger action in degrees per minute of change is of little value because it ordinarily does not correlate all of the variables. Sensing the inlet and outlet blood temperatures at a known blood flow eliminated many other variables and yielded information usable by any medical engineer.

The author is indebted to the staffs of St. Joseph's Research Laboratory, St. Paul, and Phelan Manufacturing Company, Minneapolis, for valuable technical assistance.

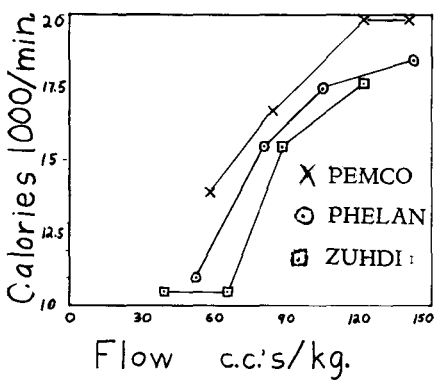

Figure 1.

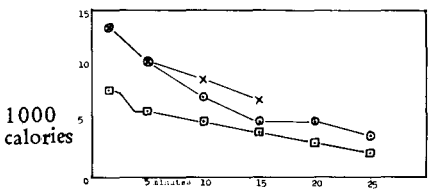

Figure 2. - Warming - Flow 80 cc/kg

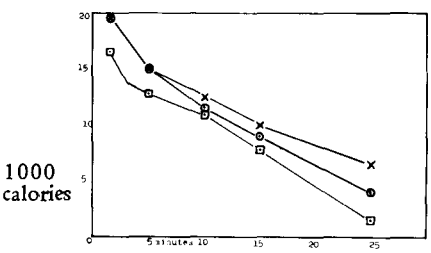

Figure 3 - Cooling - Flow 80 cc/kg